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# THE INFLUENCE OF VARIATIONS OF TEMPERATURE UPON THE RATE AND THE WORK OF THE HEART OF THE SLIDER TERRAPIN. (PSEUDEMYS RUGOSA.)

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In the studies from the Biological Laboratory of the Johns Hopkins University, vol. iii, No. 2, I briefly described the results of some experiments made on the heart of the frog and terrapin with regard to the influence upon them of oxygenated and non-oxygenated blood, and of blood in various degrees of dilution. These results showed very clearly that the influence of oxygenated blood upon the heart with regard to both its rate and work done in a unit of time was a most decided one. The manner in which oxygenated and non-oxygenated blood was prepared was as follows: A quantity of defibrinated calf's blood was previously mixed with an equal volume of Ringer's saline, divided into two portions and each portion put into a bottle; one was allowed to stand quiet for a while, the other was shaken up for a few seconds every now and then until a perceptible difference in color was noticed. This was brought about in from five to ten minutes. Then the contents of these two bottles were turned into separate Mariotte's flasks, which were connected with inflow cannulas inserted into the great veins leading directly into the sinus, and when the time came for an observation the blood was allowed to run through the heart and its effect noted. It was noticed that the rate and the amount of work were always increased on supplying the heart with oxygenated blood; the former was increased from one to five beats per minute, the latter all the way from 30 to 175 per cent. A very slight agitation of the blood before returning it into the flask would increase the work done, even when the difference in color was not perceptible to the eye, a point of great importance in connection with experiments with drugs on the heart.

The results of the second group of experiments were, that the maximum amount of work was not done by the heart when supplied with simple undiluted defibrinated calf's blood. As a diluent the often-quoted Ringer's saline was used, the composition of which is as follows:

| | *c. c.* |
|---|---|
| Normal salt solution (0.75 per cent.) | 100 |
| Calcium chlor. sol. (1.390) | 5 |
| Sod. bicarb. sol. (0.50 per cent.) | 2.5 |
| Sol. pot. chloride (1.0 per cent.) | 0.75 |

With this saline mixture, the different nutrient liquids used in the experiments were prepared; the proportions varied all the way from one of blood to one of the saline, to one of blood and twenty of the saline. Most any of these solutions supplied to the heart in the usual manner from Mariotte's flasks caused the heart to yield more work than the simple defibrinated mammalian blood, but the mixture which proved the most favorable to the performance by the heart of normal and uniform work for any length of time was found to be the one in which equal volumes of blood and Ringer's saline had been used. Hence this proportion was used as a normal nutrient in all the subsequent experiments of this nature.

I propose here to supplement the above results by some recent experiments made with a view of ascertaining the influence of blood of different temperatures on the rate and work of the heart of the slider terrapin.

From the time when Calliburces (Claude Bernard, Système Nerveux, 392) first studied the influence of variations of temperatures on the frog's heart, we know that the rate increased in direct proportions to the temperature of the heart, whether the latter is isolated from the body of the animal or left *in situ*. Shelsky, extending these researches (Ueber die Veränderungen d. Erregbarkeit durch die Wärme, Heidelberg, 1860), working also with the frog's heart, ascertained that the automatic movements of the heart might be kept up within temperatures ranging all the way from 0° to 40° C., but that beyond these limits they were arrested, a recurrence of beats, however, taking place upon a return of the temperature to within this physiological limit.

Cyon (Ludwig's Arbeiten, 1866, p. 43), in a most carefully conducted series of experiments on the frog's heart, found that these limits were somewhat variable; that is to say, while some hearts stop beating at temperatures varying between 30° and 40° C., others continued to beat when cooled down to −4° C. From the more recent experiments on the isolated dog's heart by Prof. H. Newell Martin (Philosophical Transactions of the Royal Society, Part ii, 1883), we have furthermore positive proof of the fact that the rate of beat of the mammalian heart is directly dependent on the temperature of the fluid circulating through that organ, and that the increased pulse-rate in the condition known as *fever* can be sufficiently accounted for by the increased temperature which the blood assumes during its course through the inflamed organs.

While, then, the relation of the rate of beat of the heart of both warm and cold blooded animals to variations of temperature is pretty well understood and established, the same can hardly be said as being equally true with regard to the *work done*. In those pharmacological experiments on the hearts of cold-blooded animals, according to the method which will be found described in the July number of the American Journal of the Medical Sciences for 1885, the amount of work done by the heart forms one of the most important factors in the conclusions to be derived. It is, therefore, of great importance to ascertain also the exact bearing of temperature upon the work done. So far as we are able to find this has never been done by *direct measurement.* Cyon (*loc. cit.*) ascertained it by calculation; direct measurement was impossible, according to the method which he used.

In the two subjoined experiments the temperature of the feeding fluids was ascertained by an extremely delicate thermometer, which was inserted into the common outlet tube, situated between the heart and the supplying Mariotte's flasks. The intention being to keep within the working limits of the temperature, the latter, in the two experiments, varied from 3° to 20° C. To produce a change in the temperature of the nutrient fluids, the flasks were either surrounded with ice or placed in a vessel containing hot water.

As a general rule, it may be stated that the amount of work done by the heart increases in direct proportion to the temperature of the circulating medium up to a certain limit, in the same way as does also the rate. But these two experiments show more than that. As will be seen, one was made in February and the other in the month of May. The highest temperature used in the former was 18° C., the rate being 46 per minute, the work done only 30 c. c. per minute. This was by no means the greatest amount of work done during the entire experiment; on the contrary, the maximum amount was obtained under a temperature of 12° C., the rate being 35 per minute. This shows the influence of the season upon the maximum limit of the work produced by temperature variations. This limit, in a winter animal, is accordingly at about 12° C. It is different with the rate, which, apparently, was still on the increase at 18° C., and since this was the highest temperature used in the experiment, its limit cannot be said to have been reached at all. The conclusion, therefore, to be derived from this experiment is that the maximum limit of the rate and the maximum limit of the work done by the heart of the terrapin do not necessarily correspond to the same degree of temperature of the circulating medium; the latter is reached much sooner than the former.

In the experiment made during the month of May the highest temperature used was 20° C., and here we see that neither of the two maximum limits have been reached under that temperature, but that, on the contrary, they still move together. The rate is about half of that in the February experiment under the same temperature, showing that the same temperatures affect the heart of cold-blooded animals differently in different seasons of the year, both as regards the rate as well as the work done. The maximum limit of the work produced lies much higher in spring animals than it does in winter animals. Thus, the influence of the season, by a comparison of these two experiments, is, I think, very well shown.

The practical deductions to be drawn from these experiments must, of course, be that a strict account of all variations of temperature of the supplying liquids must be taken during the course of an experiment. This becomes more especially necessary when working in a room which is artificially heated and subject to sudden changes. A fact worth noting in this connection is the peculiar systolic standstill which was produced by the sudden change of the supplying fluids from a lower to a higher temperature. During this systolic arrest the ventricle became exceedingly small, looking pale and bloodless, while the auricles became very much enlarged and overdistended with blood, which they were unable to force into the contracted ventricle. This apparently shows that warmth is a most decided cardiac stimulant, especially so far as the ventricle is concerned. As, however, the temperature became equalized the ventricle began to become gradually relaxed and admitted the blood from the overdistended auricles, which, in spite of their having been much overdistended for sometimes one-half minute, showed not the slightest sign of weakening.

## Experiment IV.

[February 7, 1885. Terrapin, 680 grms. Brain and spinal cord destroyed. Heart exposed. Canulas in left superior and inferior venæ cavæ and in right and left aortæ. Pig's blood and Ringer's saline used as a nutrient in the proportion of 1 : 1. Venous pressure, 3.5 c. m. Arterial pressure. 15 c. m.]

| Time p. m. | Temperature. | Rate per minute. | Work (in cubic centimeters) per minute. | Time p. m. | Temperature. | Rate per minute. | Work (in cubic centimeters) per minute. |
|---|---|---|---|---|---|---|---|
| *h. m.* | °*C.* | | | *h. m.* | °*C.* | | |
| 12 30* | ...... | ...... | ........ | 2 35 | 5 | 5 | 14 |
| 1 00 | 7 | 12 | 23.5 | 40 | 4.5 | 5 | 14 |
| 05 | 7 | 12 | 23.5 | 43 | 55 | 5 | 21.5 |
| 10 | 6 | 9 | 22.5 | 45 | 11.5 | 14 | 29 |
| 15 | 6 | 9 | 22.5 | 47 | 12.5 | 15 | 32.5 |
| 20 | 5.5 | 8 | 20 | 50 | 12.5 | 15 | 32 |
| 25 | 5 | 8 | 17.2 | 55 | 7 | 7 | 20 |
| 30† | 5 | 8 | 18 | 58 | 5 | 5 | 14 |
| 32 | 4.5 | 5 | 17.5 | 3 02 | 8 | 8 | 21 |
| 35‡ | 3.5 | 3 | 12.5 | 05 | 9 | 25 | 25 |
| 40 | 3 | 3 | 12.5 | 10 | 11 | 24 | 31 |
| 44 | 5 | 7 | 21 | 15 | 11 | 25 | 29 |
| 47 | 7.5 | 24 | 27 | 20 | 11.5 | 24 | 32 |
| 50 | 10 | 25 | 32 | 25 | 10.5 | 22 | 29 |
| 52 | 11 | 25 | 32 | 28 | 8 | 7 | 24 |
| 55 | 12 | 26 | 34 | 30 | 8 | 11 | 33 |
| 58 | 8 | 10 | 25 | 36 | 8 | 11 | 31.5 |
| 2 00§ | 5.5 | 7 | 19 | 40 | 14 | 32 | 41 |
| 05§ | 4.5 | 5 | 15 | 45 | 14 | 31 | 38 |
| 10§ | 4 | 5 | 16 | 48 | 13.5 | 32 | 33 |
| 15§ | 4 | 4 | 10.5 | 51 | 13 | 32 | 32 |
| 20 | 3.5 | 4 | 8 | 55 | 11 | 23 | 38 |
| 23 | 4 | 5 | 14 | 58 | 12 | 21 | 38 |
| 25 | 6 | 8 | 27.5 | 4 08 | 18 | 46 | 30 |
| 27 | 12 | 35 | 40 | 12 | 12 | 20 | 32 |
| 30 | 12.5 | 36 | 42 | Experiment discontinued. | | | |
| 33 | 7 | 8 | 21 | | | | |

* Terrapin in box.

† Auricles contracting sluggishly.

‡ No auricular systole occurred.

§ Five long tonic ventricular contractions to one imperfect and incomplete auricular.

## Experiment XXXI.

[May 4, 1885. Terrapin, 1,640 grms. Brain and spinal cord destroyed. Heart exposed. Inflow canulas in left superior and inferior venæ cavæ. Outflow canulas in right aorta and pulmon. artery. Calf's blood and Ringer's saline (1 : 1). Venous pressure, 5 c. m. Arterial pressure, 25 c. m.]

| Time p. m. | Temperature. | Rate per minute. | Work (in cubic centimeters) per minute. | Time p. m. | Temperature. | Rate per minute. | Work (in cubic centimeters) per minute. |
|---|---|---|---|---|---|---|---|
| *h. m.* | °*C.* | | | *h. m.* | °*C.* | | |
| 2 00* | ...... | ...... | ...... | 44 | 13 | 15 | 52 |
| 30 | 20 | 29 | 70 | 47 | 16 | 20 | 57 |
| 40 | 20 | 29 | 69 | 50 | 18 | 31 | 72 |
| 50 | 20 | 29 | 69 | 54 | 20 | 32 | 74 |
| 57 | 20 | 29 | 70 | 4 01 | 14 | 20 | 52 |
| 3 00 | 18 | 27 | 62 | 05 | 13 | 16 | 52 |
| 02 | 14 | 17 | 55 | 07 | 12 | 15 | 52 |
| 06 | 20 | 34 | 75 | 11 | 13 | 15 | 55 |
| 10 | 12 | 12 | 50 | 14 | 19 | 31 | 67 |
| 15 | 20 | 33 | 70 | 25 | 18 | 26 | 57 |
| 18 | 17 | 26 | 51 | 4 27 | 10.5 | 11 | 40 |
| 21 | 11 | 15 | 50 | 30 | 9 | 10 | 41 |
| 25 | 16 | 24 | 57 | 33 | 11 | 12 | 50 |
| 28 | 20 | 34 | 70 | 35 | 12 | 14 | 55 |
| 37 | 15.5 | 21 | 55 | 39 | 18 | 28 | 65 |
| 39 | 15 | 18 | 50 | Experiment discontinued. | | | |
| 42 | 13 | 16 | 50 | | | | |

* Terrapin in box.

NOTE.—Every sudden change in the temperature of the circulating fluid admitted into the heart from low to high causes an immediate systolic ventricular standstill, lasting about 30 seconds, the auricles in the mean time becoming distended until from 3 to 4 times their normal size.

### EXPLANATION OF PLATES.

Plate XVI is a graphic representation of Experiment XXXI.

Plate XV represents the different tracings attained under the various temperatures, from the same experiment, the long tonic ventricular systoles under the influence of the lower temperatures contrasting very remarkably with the quick energetic stroke of the ventricle under the influence of the higher temperatures.

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# DESCRIPTION OF A NEW SPECIES OF PEMPHERIS (PEMPHERIS POEYI) FROM CUBA.

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The United States National Museum possesses Professor Poey's type of *Pempheris mülleri*, and in the same bottle with it I have recently discovered a smaller specimen of a *Pempheris*, which is distinct from the type of Poey's description and appears to represent a species which is different from all of those hitherto described, so far as I am aware.

The type of the present description has received a new catalogue number, 37184. The length of the typical specimen to the base of the caudal is 46 millimeters. The species may be at once distinguished from *P. mülleri* by (1) the much larger scales on the sides, (2) its smaller eye, and (3) the much smaller number of rays in its anal fin.